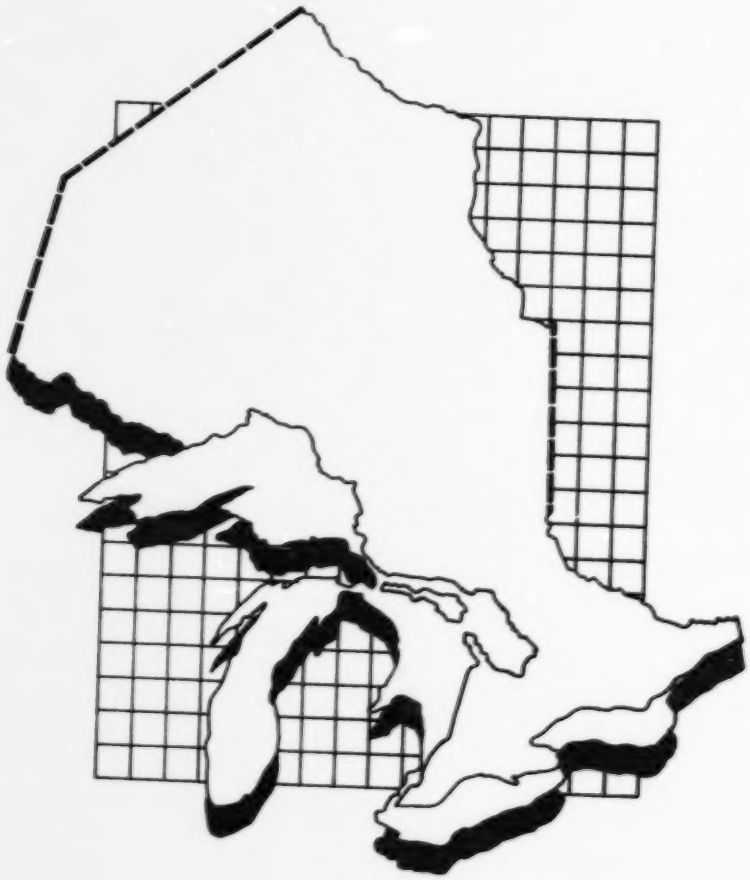
Solar Zoning Techniques



Ontario

Ministry of Energy

Honourable Robert Welch,Q.C. Minister

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SOLAR

ZONING

TECHNIQUES

A discussion paper prepared for the

Ontario Ministry of Energy

by

A. J. Diamond Associates

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Executive Summary

In summary, the conclusions of this study of Solar Zoning Techniques are as follows:

1. The use of passive solar energy for space heating can be an effective supplement to conventional energy sources in Ontario particularly in low density residential development. Thus zoning to protect present and future solar access is an important consideration for both Ontario's energy and land use planning policies.

2. Zoning by-laws to protect solar access can be successfully achieved in most new low density residential developments, and in many existing low density neighbourhoods in Ontario.

3. The Planning Act, existing and proposed, contains no major barriers to solar zoning by a local municipality. However, vegetation, which can be a serious source of shading, cannot be effectively controlled under the existing or proposed Planning Act.

4. In Ontario latitudes, solar access zoning for medium density residential development (30-80 units per hectare) produces some constraints on the form and layout of the buildings. The trade-off between the benefits of passive solar gain, and the loss of design amenity must be considered before enacting solar zoning for new medium density development.

I Introduction

The Province of Ontario has adopted an overall Provincial energy policy which includes a solar energy target of 2% of Ontario's energy needs to be provided from solar energy by 1995, or the equivalent of space heating for more than 700,000 Ontario homes per year. Achieving this target will require a significant recognition by Ontario municipalities of the importance of land use planning for both active and passive solar systems. One of the most important elements in such local planning policy is the ability to protect the individual property owner's right to sufficient access to sunlight to ensure that present and future solar systems are effective.

The purpose of this manual is to provide municipal planners with an understanding of the implications of solar access protection for new and existing development, and with practical methods to effectively ensure solar access. The focus of the manual is on the use of zoning by-laws as a means to protect solar access. While there are other legal tools, such as covenants and easements agreements between individual property owners, these are difficult to establish and maintain and ineffective for larger areas. Consequently it is generally recognized that the zoning by-law is the best tool currently available for comprehensive solar access protection.

A brief overview of the basics of sun and movement shadowing, current solar space heating technology and the use of a solar zoning by-law is provided.

1. Basic Solar Concepts

The basic concepts involved in the use of solar energy for space heating and cooling are well described in a number of publica-

tions, including the Ministry of Energy's Turn on the Sun, Revised Edition, 1978. A brief review of these fundamental concepts of solar zoning will be provided here.

Position of the Sun in the Sky

In order to understand the changing pattern of sunlight falling on any location, and thus how planning may encourage or inhibit solar access, it is important to understand the way in which the sun moves across the sky.

There are three factors which affect the amount of sunlight received by any location; the sun's altitude above the horizon, its angle in relation to due south, and the latitude of the location. The altitude of the sun above the horizon is measured in degrees from 0^{o} to 90^{o} (directly overhead). The maximum altitude

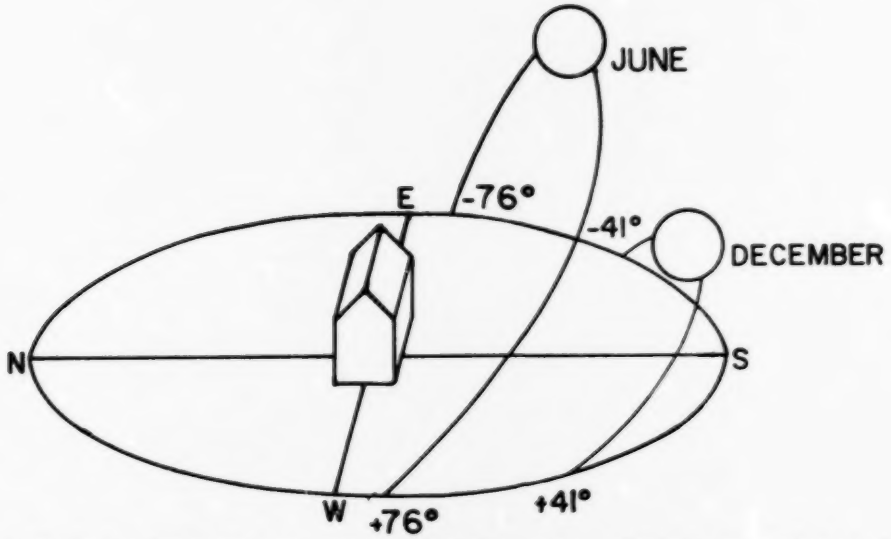


DIAGRAM I- POSITION OF SUN IN SKY- SUMMER AND WINTER, 44° N. LATITUDE

of the sun in the sky is reached at the summer solstice(June 21). It gradually declines from summer to winter, reaching its lowest altitude on December 21. Consequently the sun is above the horizon for a longer period of time in summer, allowing more solar radiation to reach Ontario than in winter when the heating period is shorter.

As the sun travels across the sky from east to west its position in relation to due south is called the azimuth, and is measured in degrees of angle, with negative values to the east and positive angles to the west of due south. For example, at sunrise the sun's altitude is 0^{o} and its azimuth is a large negative number, at sunset its altitude is again 0^{o} and its azimuth is a large positive number. Azimuth angles also change with the seasons, since the sun rises and sets further north in the summer than it does in the winter. Using both the azimuth and altitude angles, the sun's position in the sky can be determined for any time and day of the year.

Sun angles also change with latitude. The further north the latitude, the lower the angle of the sun in the sky, and these lower, more oblique angles mean that the intensity of sunlight reaching a collector is less in more northerly latitudes. At higher northern latitudes where the sun is lower in the sky, shadows are longer, making it more difficult to protect for full solar access. For example, at 44^{o} north latitude (Toronto) the highest altitude of the sun on December 21 is 22.5^{o}, while at 48^{o} north latitude (Wawa, Timmins, Chapleau, Kirkland Lake), the highest sun altitude on December 21 is 18.5^{o}, a difference of 4^{o}.

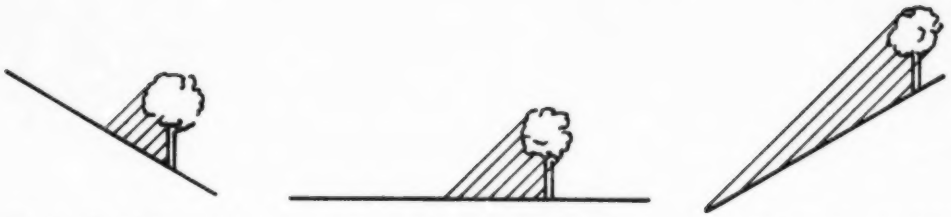
There is one other factor which affects the angle and thus the intensity of the radiation and that is the slope of the land. Changes in the slope of land also cause considerable local

variation in shadow length as shown in Diagram 2. On a south slope, where the land is tilted toward the sun, the intensity of radiation is greater and shadow lengths are short. Conversely on a north slope, the sun's rays are more dispersed and shadow lengths are increased. Variations in slope add considerable complexity for the municipal planner in evaluating the solar access at a proposed development. The following table shows the length of a shadow cast by a pole one metre in height at varying degrees of slope and in varying latitudes.

Table 1 Length of a shadow cast at noon by a pole one meter in height where the slope of ground is due north

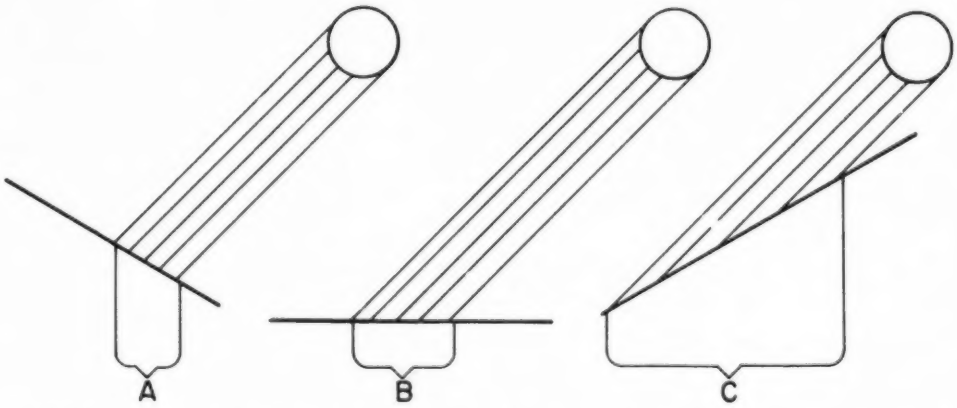
	North Latitude				
% of Slope	42°	44°	46°	48°	50°
			(metres)		
0%	1.9	2.0	2.2	2.5	2.7
5%	2.1	2.3	2.5	2.8	3.2
10%	2.3	2.6	2.9	3.3	3.8
15%	2.6	2.9	3.4	3.9	4.6
20%	3.0	3.4	4.0	4.9	6.0

Source: Sun Shadow Guide, Ministry of Energy, January 1980.



A-SOUTH SLOPE B-LEVEL GROUND C-NORTH SLOPE

SHADOW LENGTH SHORT ON SOUTH SLOPE, LONG ON NORTH SLOPE



A- GREATEST CONCENTRATION OF SUN'S HEAT ON SOUTH SLOPE
B- NORMAL CONCENTRATION ON LEVEL GROUND
C- DISPERSION OF RADIATION ON NORTH SLOPE

DIAGRAM 2- RELATIONSHIP OF SLOPE TO SHADOW LENGTH AND INTENSITY OF SOLAR RADIATION

Solar Window

A "solar window" is a way of describing the portion of the sky across which the sun travels during the period when it provides effective solar heat.

A solar collector, whether active or passive must be able to "see" a defined portion of the sky in order to be effective. In early morning and evening the sun is so low in the sky that its radiation is diffused by the atmosphere, cloud, smog and air pollution, and provides very little effective solar energy. In northern latitudes such as those prevalent in Canada, effective solar radiation is only received between 9:00 am and 3:00 pm, when almost 85% of the daily solar radiation is received. This represents an azimuth angle in Ontario of approximately 45° east and west of due south. Thus the solar window which must ideally be protected is a space in the sky defined by the 45° azimuths and the solar altitude on December 21. However, in latitudes as far

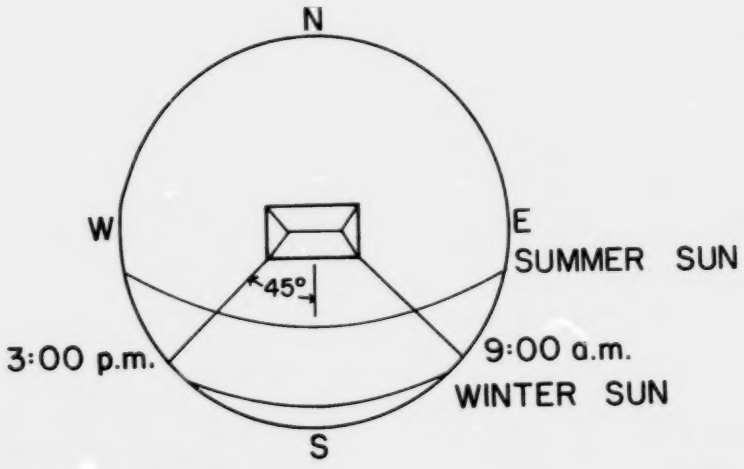


DIAGRAM 3 - SOLAR WINDOW

north as Ontario the length of the shadows cast on December 21 is so great that protection of solar access requires unacceptably low and widely spaced buildings. Consequently the solar window defined by the sun's altitude on January 21 or November 21 is accepted as the definition of effective solar access.

2. Basic Solar Energy Systems

There are two basic systems which are used to collect and employ solar energy for space heating of buildings: passive systems and active systems. Each of these has particular requirements which are relevant to the planner who must understand them in order to provide appropriate legal protection.

Passive Solar Systems

In general passive solar heating and cooling systems collect, store and transmit heat without the use of mechanical equipment. Heat is transmitted by natural means, radiation, conduction and natural convection, and the building itself, or some parts of it are elements of the system. The two basic elements of passive systems are south facing glass for collection, and mass in the form of masonry walls, floors or substances such as water, rocks or hygroscopic salts for storage and distribution.

Active Solar Systems

Active solar systems use mechanical means or equipment to collect and transmit heat. The basic elements of an active system are the collector (usually a flat plate or a curved collector which focuses and thus intensifies the sun's radiation) and a separate heat storage medium, rocks, water or some other absorptive substance. Water or air is pumped through the collector where it absorbs the sun's heat and carries it to the storage unit. A

mechanical system, usually forced air, then distributes the stored heat to the building.

3. Land Use Implications of Solar Technology

Passive solar energy can be used in all areas of Ontario to supplement conventional space heating systems, and to heat water for domestic residential use and for swimming pools. To be effective, passive solar energy for space heating requires that sunlight reach the south facing wall of the building. Active solar systems for space heating require that sunlight reach the solar collection device which may be mounted on the roof of the building or on a structure separated from the house. Passive solar heating of a swimming pool requires that sunlight reach the swimming pool and thus the garden space during the summer months.

In summary there are levels of protection of solar access to the lot and building structure, depending on the type of system used and the heating requirement. For residential space heating, which provides the greatest potential for energy savings, passive systems require full south wall exposure, while active systems require roof exposure and in some circumstances protection of garden space in which a remote collector may be located.

In Ontario, passive solar energy can provide up to 40% of the space heating requirements of standard single family housing, and of 2-3 storey medium density multiple housing, provided all units have a southern exposure with sufficient south-facing glass, air-tight construction and excellent insulation. For apartment buildings passive solar systems are not effective since normally all units cannot have a south exposure, and warm air cannot be distributed between one unit and another. Active solar systems can be used in low rise apartments where there is sufficient roof area

in relation to the number of units to make use of active systems for space heating or domestic hot water.

Consequently the emphasis in the study is on zoning to protect:

- south wall and south garden solar access in low density residential development, defined as single family housing, semi-detached and row housing at densities of up to 10 units per acre (24 units per hectare)
- south wall and roof top solar access in medium density residential development, defined as row housing, stacked town-houses, walkup apartments at densities up to 35 units per acre (84 units per hectare)

4. The Ontario Context

There is a common misconception that the use of solar energy for space heating is restricted to areas of North America which have a temperate climate and abundant sunshine. Most settled regions of Canada have severe winter conditions, and many areas suffer from long periods of cloud or overcast in winter. It must be recognized, however, that in virtually all areas of Canada there is sufficient winter sunshine to provide a highly effective supplement to conventional space heating systems. In most areas of Ontario, solar heating combined with reasonably air tight construction and improved insulation can reduce the demand for conventional energy sources by 30% to 50% or more.

Settled areas of Ontario occur across approximately eight degrees of north latitudes, roughly from 42^{o} north to 50^{o} north, representating a north-south distance of about 115 kilometres and 8 degrees of difference in the noon altitude of the sun. Major Ontario communities are situated in the following zones:

North Latitude

42^{o}-43^{o}	Windsor, Chatham, Sarnia, London, Niagara Falls
43^{o}-44^{o}	Hamilton, Kitchener, Waterloo, Toronto
44^{o}-45^{o}	Belleville, Peterborough, Kingston, Brockville, Barrie, Orillia
45^{o}-46^{o}	Ottawa, Parry Sound, Bracebridge, Huntsville
46^{o}-47^{o}	Sudbury, North Bay, Sault Ste. Marie, Blind River
47^{o}-48^{o}	Chapleau, New Liskeard
48^{o}-49^{o}	Timmins, Thunder Bay, Kirkland Lake
49^{o}-50^{0}	Geraldton, Kapuskasing, Cochrane, Kenora, Dryden
50^{o}-51^{o}	Sioux Lookout, Armstrong

For the purposes of this manual, examples will be given of latitudes at 44^{o} north and 46^{o} north, representing a typical range of situations for a large number of Ontario urban areas.

5. Precedents in Solar Access Zoning

The use of zoning regulations to protect solar access has been fairly extensive in the United States, particularly in California where the City of Davis has a solar zoning by-law as part of a community-wide energy conservation program. Colorado Springs, Pitkin County and Indio, Colorado, Albuquerque and Los Alamos, New Mexico and Largo, Florida also have such by-laws. In Canada, the City of Brampton is one of the first to have a solar zoning by-law, and several other municipalities are considering such legislation.

The City of Brampton's solar zoning by-law has been applied only to new single family residential development. In 1979 energy conservation policies were incorporated into the City's Draft Official Plan and a solar zoning by-law was approved for a residential subdivision by the Ontario Municipal Board.

In essence the Brampton solar zoning by-law applies three zoning provisions to a new subdivision. All new subdivisions are required to be laid out with as many lots as possible oriented within 20^{o} of either side of the true north-south axis. The result is that most streets run as close to the true east-west axis as possible with small interconnecting north-south streets on which solar oriented lots do not occur. The following three solar overlay categories are applied:

1) For lots on the south side of an east-west street which have a solar orientation but whose buildings will only cast shade on the street to the north, the requirement is that a main south-facing wall of the building be oriented within 20^{o} east or west of the true north-south axis.

2) For lots which cannot have a solar orientation (such as those on the north-south streets) but which lie to the south of lots which do have solar orientation a maximum building height is prescribed which assures protection of sunlight between 9:00 am and 3:00 pm on January 21 to the south wall of the lot to the north.

3) For lots which have a solar orientation, are on the north side of the street and adjoin lots which also have a solar orientation, both the provision requiring a due south exposure for a main wall, and the height restriction which assures solar access to the south wall of the building to the north are established.

The provisions of Brampton's solar zoning by-law have been applied to each new residential subdivision in the City since 1979. The by-law has been upheld by the Ontario Municipal Board, except with regard to the provision that coniferous vegetation may not

penetrate the prescribed building height plane. This by-law has been successful in producing new residential development with up to 80% of the lots having a solar orientation. Houses in the solar subdivisions are standard construction but with the addition of increased south-facing glass, air-lock entry halls and optional energy conserving items such as increased insulation and energy-saving furnace systems. With successive refinement of the solar zoning by-law's format, it is now a simple and workable document which is administered with little difficulty by City staff and is understood and well accepted by the development industry.

II The Solar Zoning Envelope

In order to protect solar access through zoning to a south facing garden, south wall or roof top, it is necessary to define the envelope within which building (and planting) can occur without casting unacceptable shade. The following section describes the way in which a solar zoning envelope is developed.

1. The Solar Envelope

Traditionally the zoning by-law provides set back requirements and maximum building heights in residential zones. These bulk regulations produce an allowable building envelope which is in effect a rectangular box over the lot defined by the set backs and height limit.

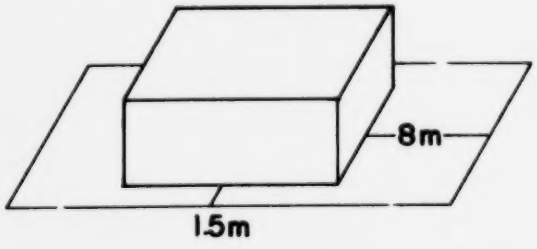
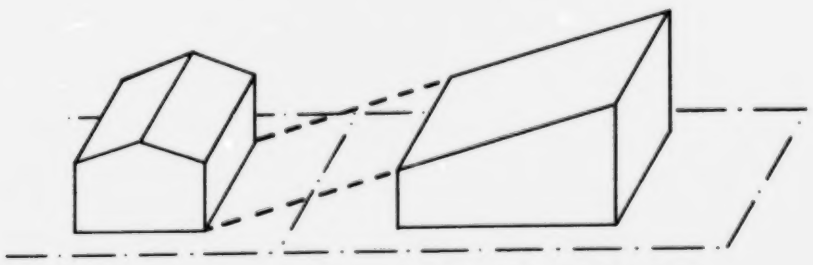


DIAGRAM 4 - TRADITIONAL ZONING ENVELOPE

A zoning envelope for solar access may be similarly constructed in which the maximum building height is defined by the 9:00 am and 3:00 pm angle of the sun at the specified latitude on January 21. Thus the top plane of the envelope is angled, rather than flat. The set back is defined by the length of shadows cast on the south wall or garden of the adjacent property by the maximum height of building within the angular plane.



NOV 21, JAN 21 SUN ANGLE

DIAGRAM 5- THE SOLAR ZONING ENVELOPE

There are three factors which can affect the size and shape of a solar zoning envelope as it is applied to varying lots across a single community:

a) Slope of the Land

As the slope changes, the dimensions of the building envelope must change in order to preserve south wall solar access for buildings to the north of the envelope. Lots on a north slope require a shallower angle and thus lower buildings and wider setbacks than lots on level ground. Similarly lots on a south slope produce a building envelope which allows greater height and closer spacing of buildings. Consequently in communities with considerable variation in topography there may be a wide variety of envelope dimensions.

b) Orientation

It is not possible to orient all lots along an east-west axis. Street grids vary in response to existing road patterns and topographic variation, and there are always of necessity some north-south streets. Consequently all lots in a community cannot have an ideal north-south orientation. The shape and dimensions of the solar building envelope will differ considerably between a north-south lot and an east-west lot, while lots which are angled away from the cardinal points again have differing envelopes.

c) Standard Block Dimensions

Standard block dimensions and typical lot dimensions and street widths vary from one residential area to another. In areas where blocks are deep, and lots are long and narrow, the bulk, height and slope of the envelope will be different from areas where the blocks are shallow with relatively wide lots.

Each of these three factors can change the angle and shape of the top plane of the solar envelope. Angular planes can also be introduced on the sides of the envelope.

The Shaved Envelope

Where single family lots or buildings are staggered, or there is a wish to ensure solar access to east or west facing walls of lots to the east and west of the lot for which the solar envelope is developed, a "shaved" envelope may be constructed. The shaved envelope is developed with solar angles running across the width

of the lot in addition to the angular planes running from north to south. These additional solar angles also begin at the point which defines the protected area on the adjacent lot. Diagram 6 illustrates a shaved envelope which protects solar access to the east and west walls of the houses east and west of the lot in question.

In theory this type of envelope provides excellent solar access protection to buildings around it. However, it must be recognized that its calculation is complex, particularly where lots do not have a true north-south orientation. A site specific envelope must be calculated for each lot and site circumstance, making the application of the shaved envelope difficult to achieve in a zoning by-law. Computer programs have been developed which can generate specific solar envelopes for each lot, taking into account both topography and orientation.* Without such a program the use of shaved envelopes is probably impractical on an area wide basis.

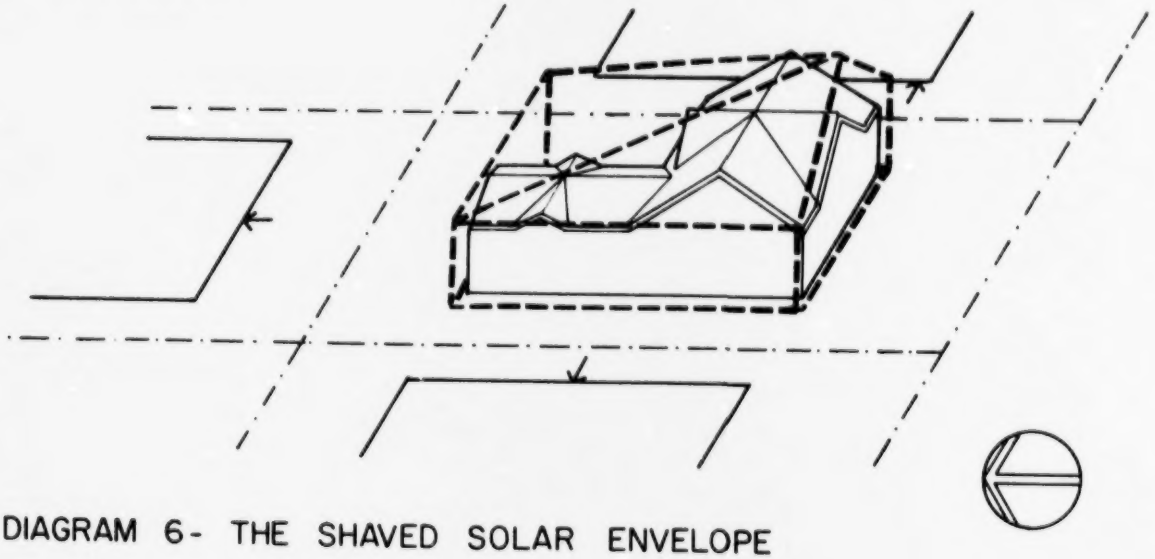


DIAGRAM 6- THE SHAVED SOLAR ENVELOPE

← WALLS PROTECTED FROM SHADING

* Knowles, Ralph L., Solar Envelope Concepts, Moderate Density Applications, Richard D. Berry, Solar Energy Research Institute, April 1, 1980.

2. Application of the Solar Envelope to Typical Forms of Residential Development

The following sections will examine the construction and use of solar zoning envelopes applied to low, medium, and high density residential development. In each case an existing residential development has been examined, in order to illustrate the practical problems which arise for the planner in dealing with solar energy.

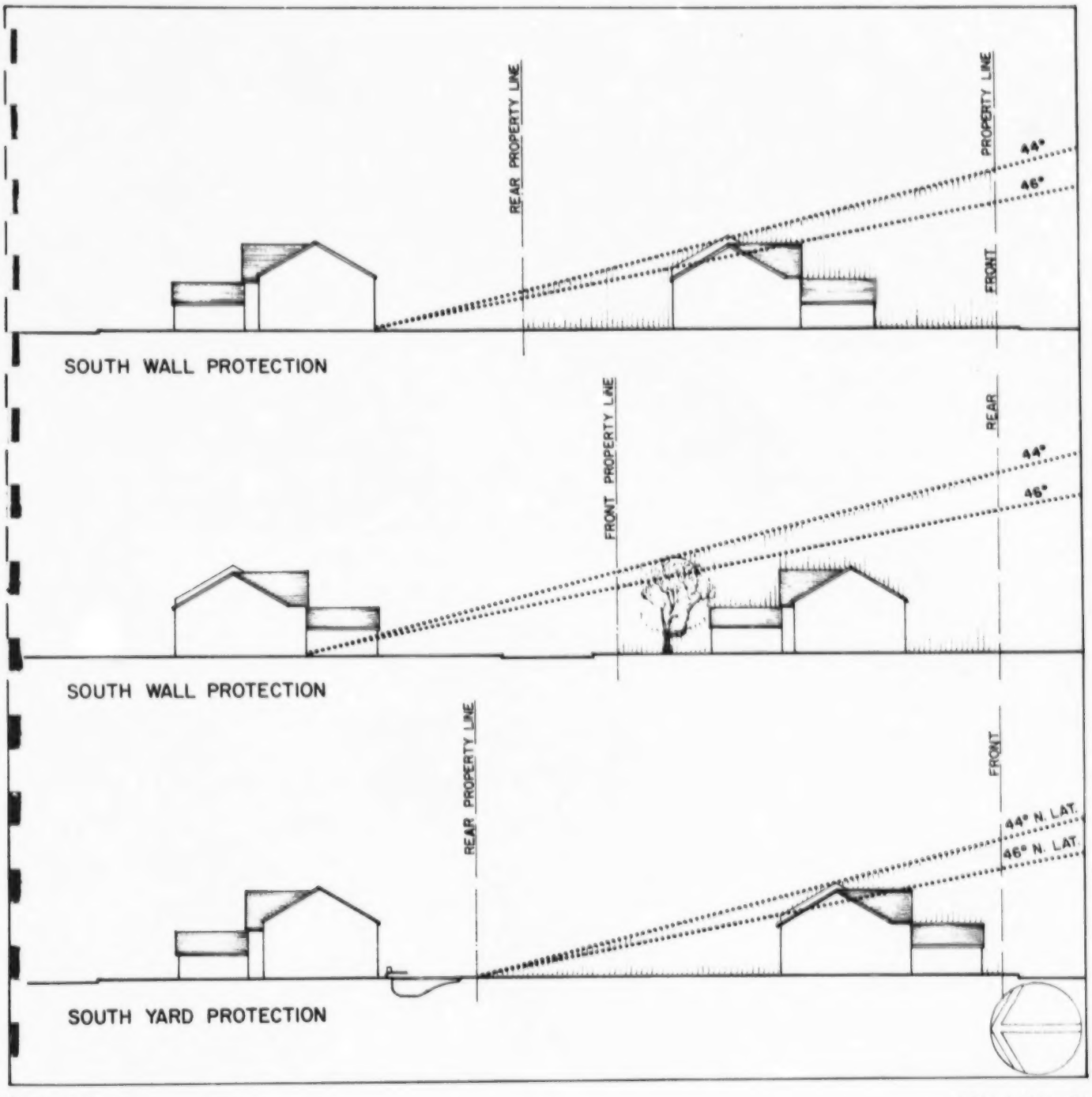
a) Low Density Development: Building Envelopes

The following series of illustrations have been developed to show the application of solar building envelopes to an existing new single family subdivision. Typical of new subdivision development across Ontario, this housing is not oriented consciously to take advantage of solar gain. Diagram 7 shows ten houses on a cul-de-sac with their actual orientation to due north-south.

Diagram 8a shows these houses in section with the existing typical front and rear set backs, and street width, with building envelopes which protect both south wall and south garden. The difference in the envelope height plane between 44° and 46° north latitude is indicated, and it can be seen that at 46° north latitude a deeper rear yard set back (37 metres spacing at 44°, 45 metres spacing at 46°) is required to give full south wall access between adjoining north-south lots.

Diagram 8b shows the solar access requirements for the same development on a variety of sloping sites. Diagram 9 illustrates the solar envelope required in a typical subdivision for south wall access, where houses face each other across a street and across a rear garden. In this case the houses are aligned on a true north south axis.

DIAGRAM 7
EXISTING - LOW DENSITY DEVELOPMENT



AGRAM 8a
OLAR ENVELOPES- LOW DENSITY

NOV. / JAN. 21
9 a.m. & 3 p.m.

0 5 10 15 20 metres

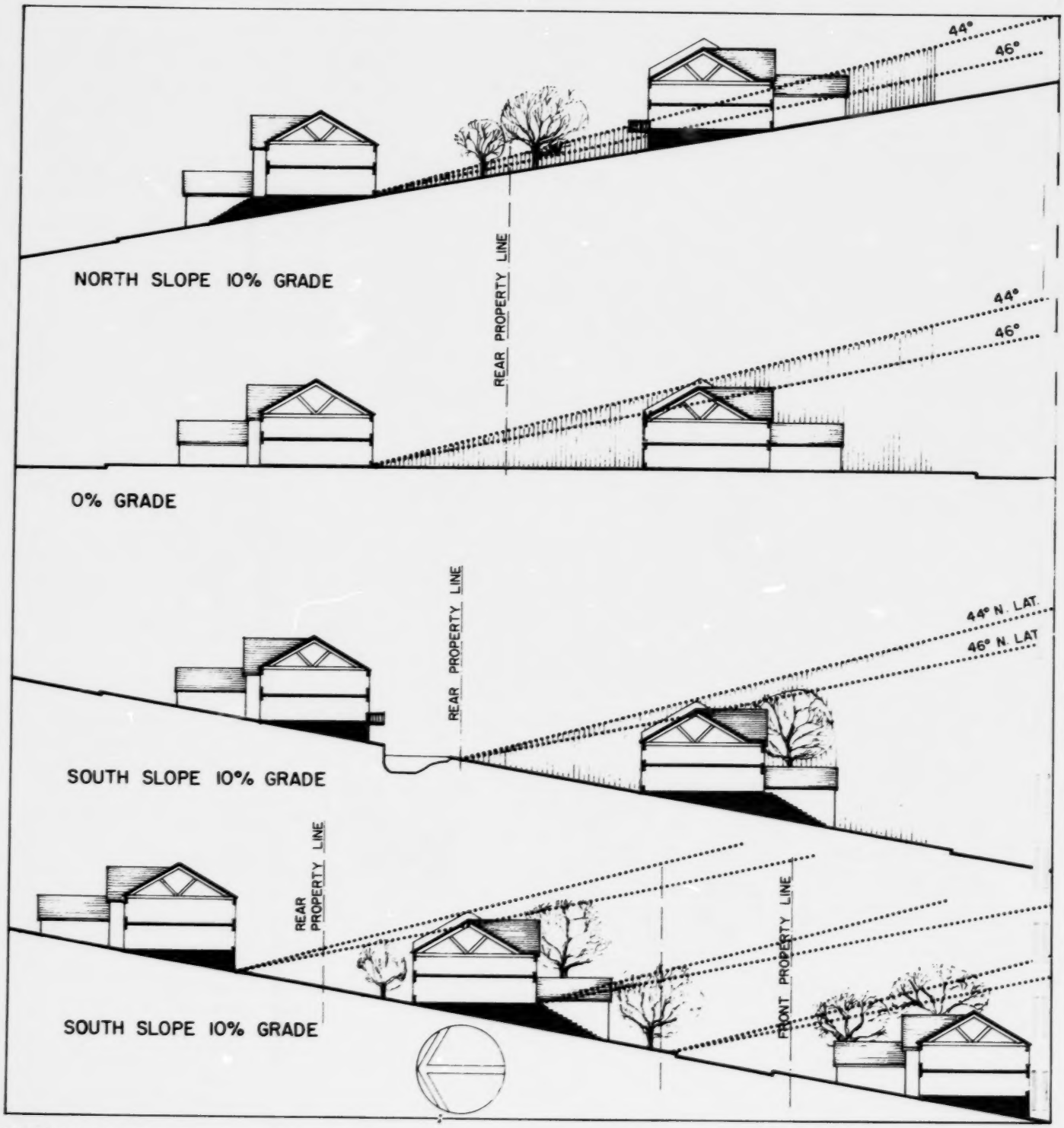


DIAGRAM 8 b

SOLAR ENVELOPES- SOUTH WALL AND SOUTH GARDEN ACCESS

NOV. / JAN.
9 a.m. & 3 p.

0 5 10 15
me

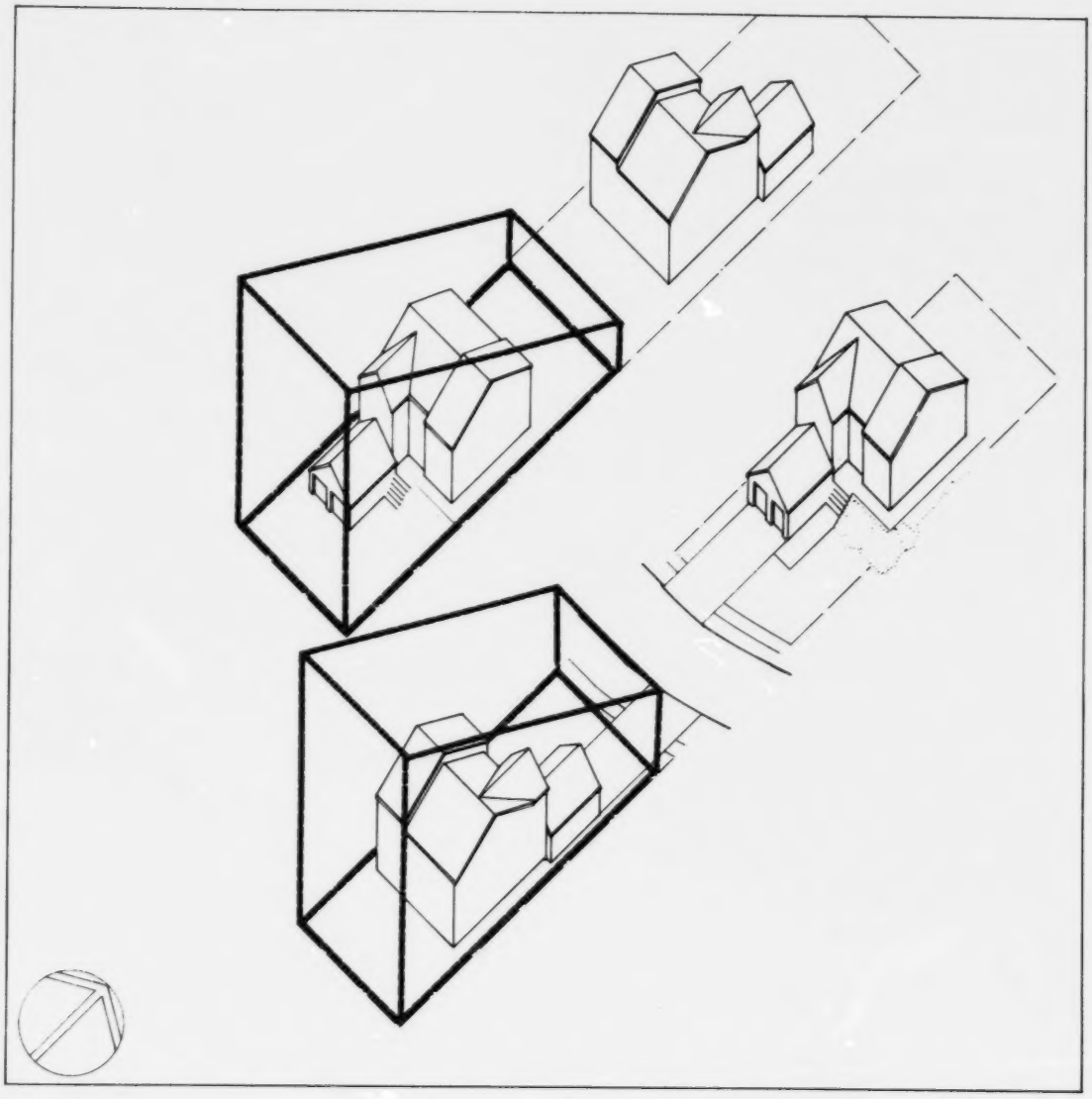


DIAGRAM 9
SOLAR ENVELOPES- LOW DENSITY

NOV. / JAN. 21
9 a.m. & 3 p.m.

0 5 10 15 25
metres

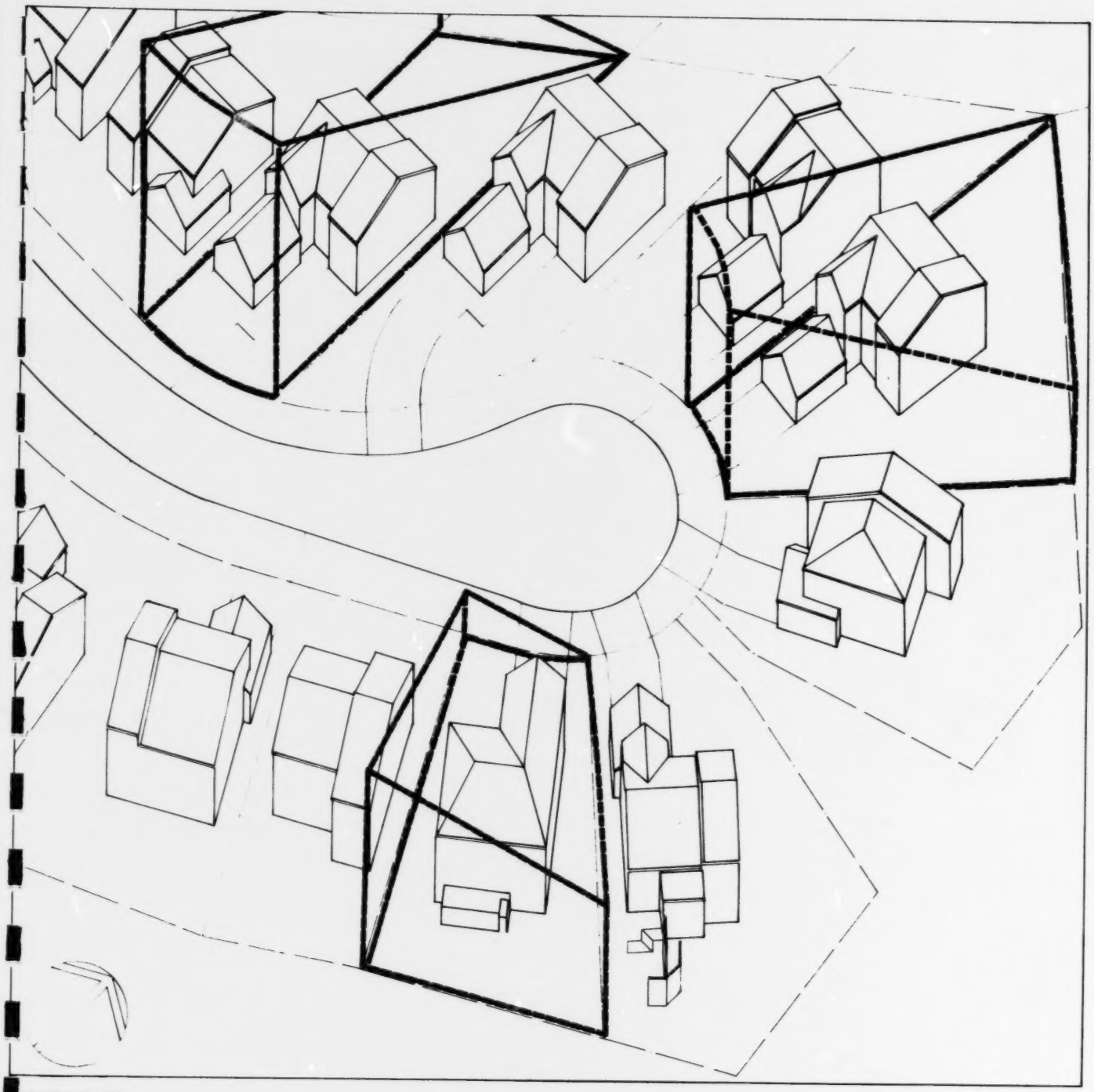
Diagram 10 constructs the actual solar building envelopes over the subdivision houses, with their true orientation. It can be seen that these envelopes differ considerably as the orientation of the houses changes from one lot to another. Consequently the irregular layout of lots which is typical of new subdivision development poses considerable complexity for the planner in developing uniform solar access building envelopes which can be incorporated in a city-wide zoning by-law. Where the terrain is sloping, this complexity is aggravated. Diagram 10 shows the difficulty of clearly illustrating in graphic form the solar zoning envelope where the orientation is irregular.

In summary in the low density situation lot sizes and setbacks of a typical single family subdivision are sufficient to permit for many of the houses south wall solar access at 44^{o} north latitude. With slight modifications to the buildings to maximize south facing glass and increase levels of insulation and air-tight construction, many of these houses could make use of passive solar heat.

At 46^{o} slightly greater lot depth and rear yard setback is required. However, for a subdivision which is not designed to maximize solar access with regular north-south orientation of lots, the complexity of a zoning by-law based on a solar building envelope is evident. Chapter III of this report will discuss solutions to this problem in greater detail.

b) Medium Density Development: Building Envelopes

The following series of illustrations shows the application of solar envelopes to medium density development.



IAGRAM 10
SOLAR ENVELOPES- EXISTING LOW DENSITY DEVELOPMENT

NOV. / JAN. 21
9 a.m. & 3 p.m.

0 5 10 15 25
metres

The application of solar building envelopes to medium density housing produces some design constraints due to the increased densities and heights required in medium density housing. Diagram 11 shows a stacked townhouse development, an infill project in an existing low density residential neighbourhood. The form is typical of medium density townhousing which encloses a small interior semi-private courtyard. This form, which is often used in rowhousing design (with minor modifications) was tested for its success in achieving solar access.

Diagram 12 is an illustration of the solar building envelopes which protect solar access to the south wall of the east-west oriented rows. The north-south oriented rows have no south facing walls, and cannot make use of passive solar gain. Moreover they cast some shade during part of the effective heating period on the south wall of the east-west building. The result is that only about 35% of the units have full solar access. Diagram 13 illustrates in cross section the solar envelope for this medium density development on level ground and on a 10^{o} north and south slope at 44^{o} and 46^{o} latitude. The spacing across the courtyard (approximately 30 m) is sufficient to allow full south wall solar access on a level slope at 44^{o}. However at 46^{o} and on a north slope a greater separation between townhouse rows is required. It is clear that south sloping sites are particularly suitable for medium density development which has solar access.

In order to achieve ideal south wall solar access to all units in multiple housing the formal organization of the units can only be in regular rows oriented within 20^{o} east or west of due south. Consequently full solar orientation of medium density houses produces some constraints on the design and densities of such housing:

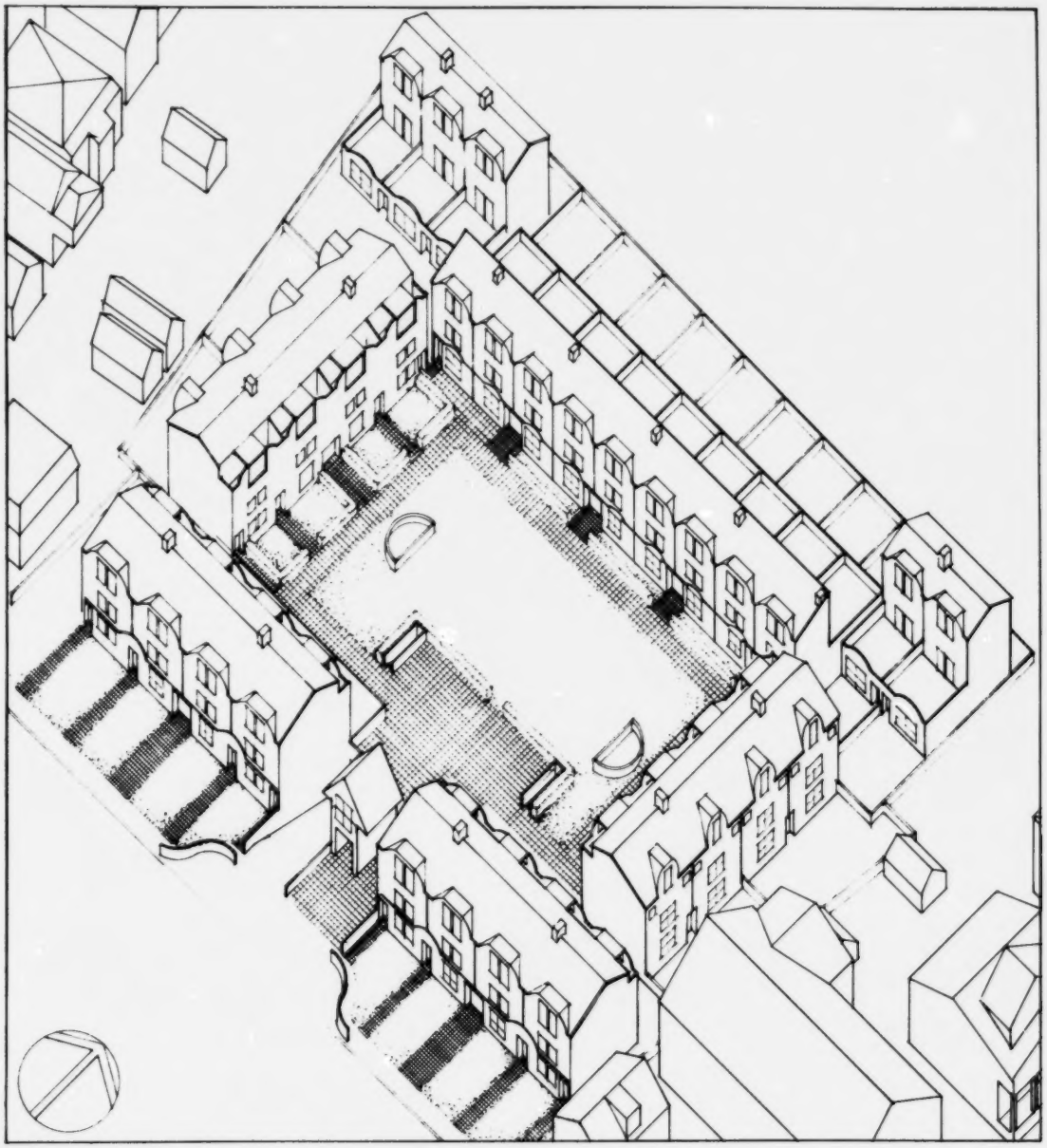


DIAGRAM II
EXISTING- MEDIUM DENSITY DEVELOPMENT

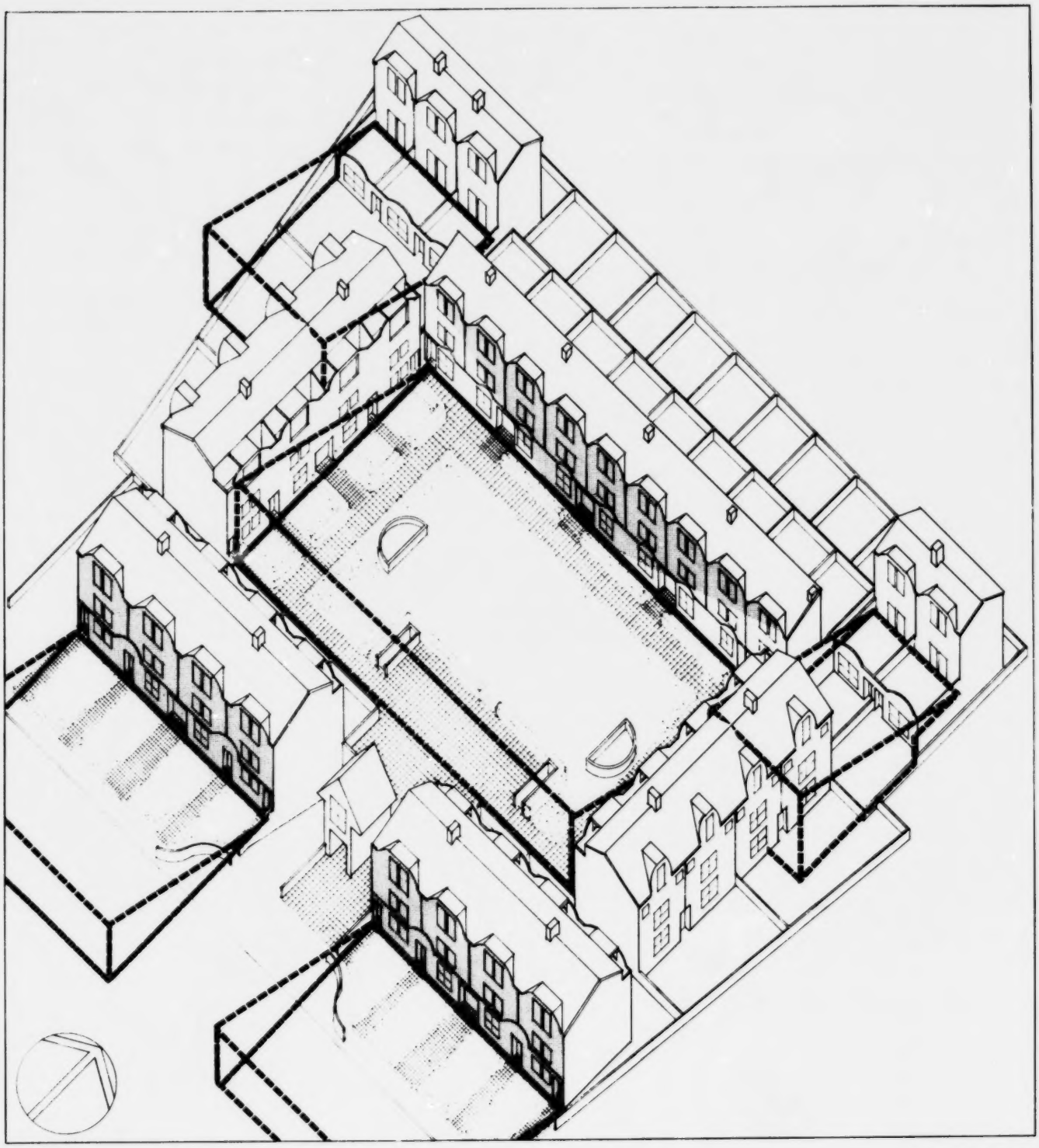


DIAGRAM 12

SOLAR ENVELOPES - MEDIUM DENSITY

NOV. / JAN. 21
9 a.m. & 3 p.m.

0 5 10 15 25
metres

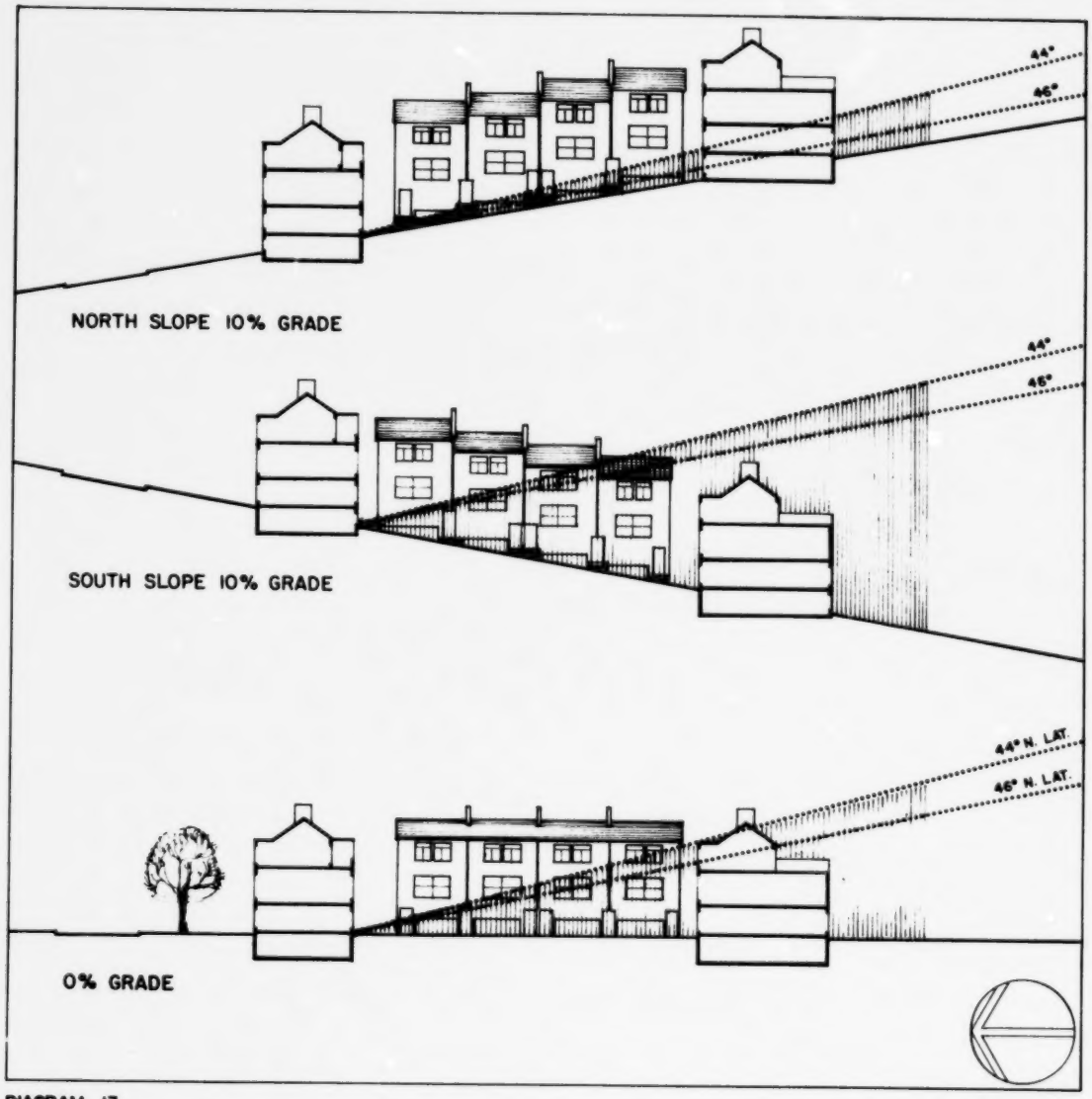


DIAGRAM 13

SOLAR ENVELOPES- MEDIUM DENSITY

NOV. / JAN. 21
9 a.m. & 3 p.m.

1) The ideal solar layout is in undifferentiated east-west rows with a constant front and rear yard set back. Building configurations which enclose courtyards, or step backwards and forwards, can provide considerable amenity. The loss of this amenity may not be an acceptable trade-off for the achievement of passive solar gain.

2) All units must have south wall exposure and consequently, low rise apartments with north facing units opening from a central corridor are not acceptable as medium density solar housing. The requirement that all units have a south wall increases overall development costs and may be uneconomic for lower income segments of the medium density housing market.

3) Density levels are constrained by the need to provide solar access to all units. Investigation for this and other studies* of medium density housing using passive solar energy indicates that a density of 25-30 units per acre (10-12 units per hectare) is the maximum that can be achieved in standard housing forms (assuming an average unit size of 1,000 square feet or 93 square metres) with all units having unobstructed south wall solar access.

In summary, while passive solar energy can be used effectively to supplement conventional heating systems in medium density housing, the need to provide unobstructed south wall solar access requires significant trade-offs of design, density and economic construction. Perhaps the most serious of these is the design constraint, since the required regular site layout precludes options for courtyard housing forms and articulation of the facades which create some of the most attractive examples of this density and housing type, as illustrated in Diagram 14.

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* Passive Solar Energy & Housing Prototypes, Doru Iliesciu, submitted to the CMHC, Open Scholarship 1978/79, May 1980.

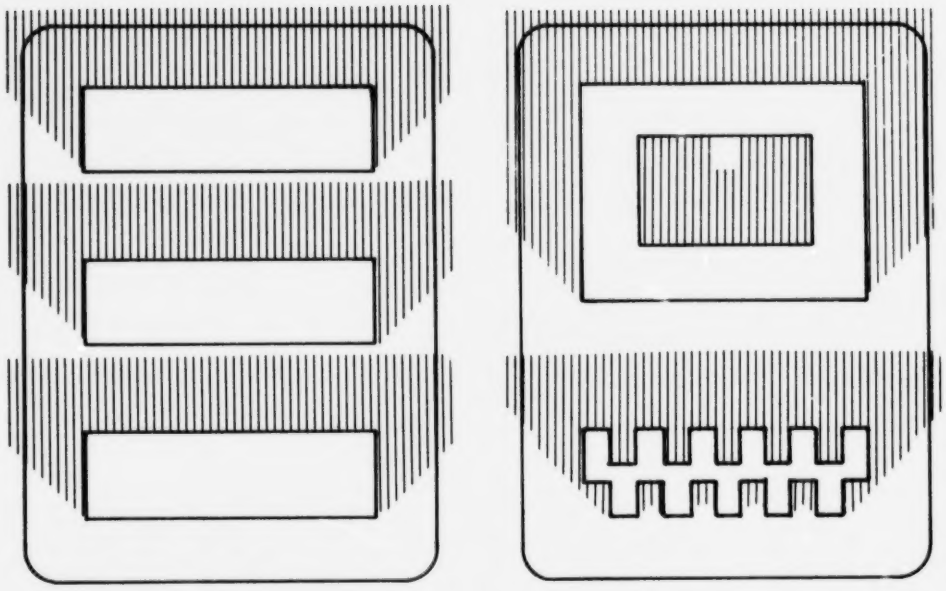


DIAGRAM 14- MEDIUM DENSITY HOUSING FORMS: SHADOW EFFECTS

Maximum densities available with solar orientation are at the low end of the medium density range and effectively eliminate housing at 35 - 60 units per acre (15 - 25 units per hectare); housing densities which are more energy efficient in terms of land use and transportation. It may be that the development of standards for insulation and air-tight construction provide more effective means of energy saving in space heating for new medium density housing than the rigid enforcement of solar access requirements.

c) High Density Development: Building Envelopes

The practical use of solar building envelopes for high density residential development is limited to the protection of sunlight to the roofs of buildings. The application of passive or active solar systems to high rise, high density housing is limited, due to the difficulty of orienting more than a fraction of units to

the south, the kinds of heating and air conditioning systems which are effective for high density housing, and the relatively small roof area in relation to the number of units. There is some potential to use roof top solar collectors to provide a supplement to conventional hot water systems in apartment buildings.

Diagram 15 shows two typical high rise apartment buildings with the building envelopes required to protect roof top solar access. It can be seen that roof top solar access can be readily achieved where high rise buildings are similar in height, without a loss of density, or a change in traditional forms.

Diagram 16 shows these two high rise buildings in juxtaposition with their actual immediate neighbours to the north, a row of traditional single family houses. The solar envelope shown is that required to protect the south walls of the existing low rise housing. The shaded area of the apartment towers indicates the extent to which they exceed the solar envelope.

This is a typical situation of transition between a high rise and a low rise area. The development of high density low rise towers directly south of low density housing not only removes all possibility of future solar energy use by these properties, but also deprives these owners of sun in their gardens and south facing windows throughout the year. The use of solar zoning by-laws to protect access to sunlight in such areas of density transition is an important aspect of solar-oriented land use planning.

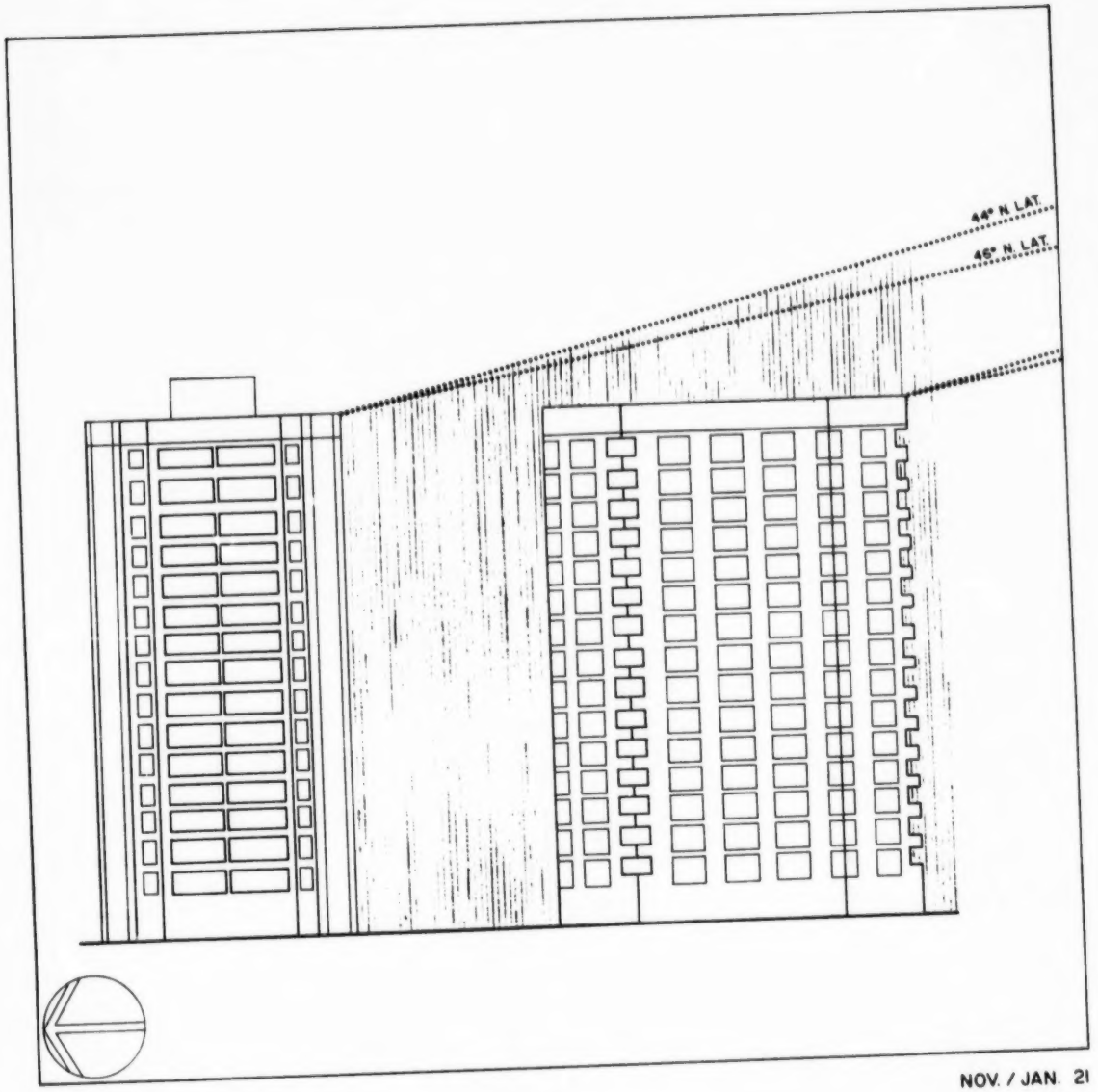
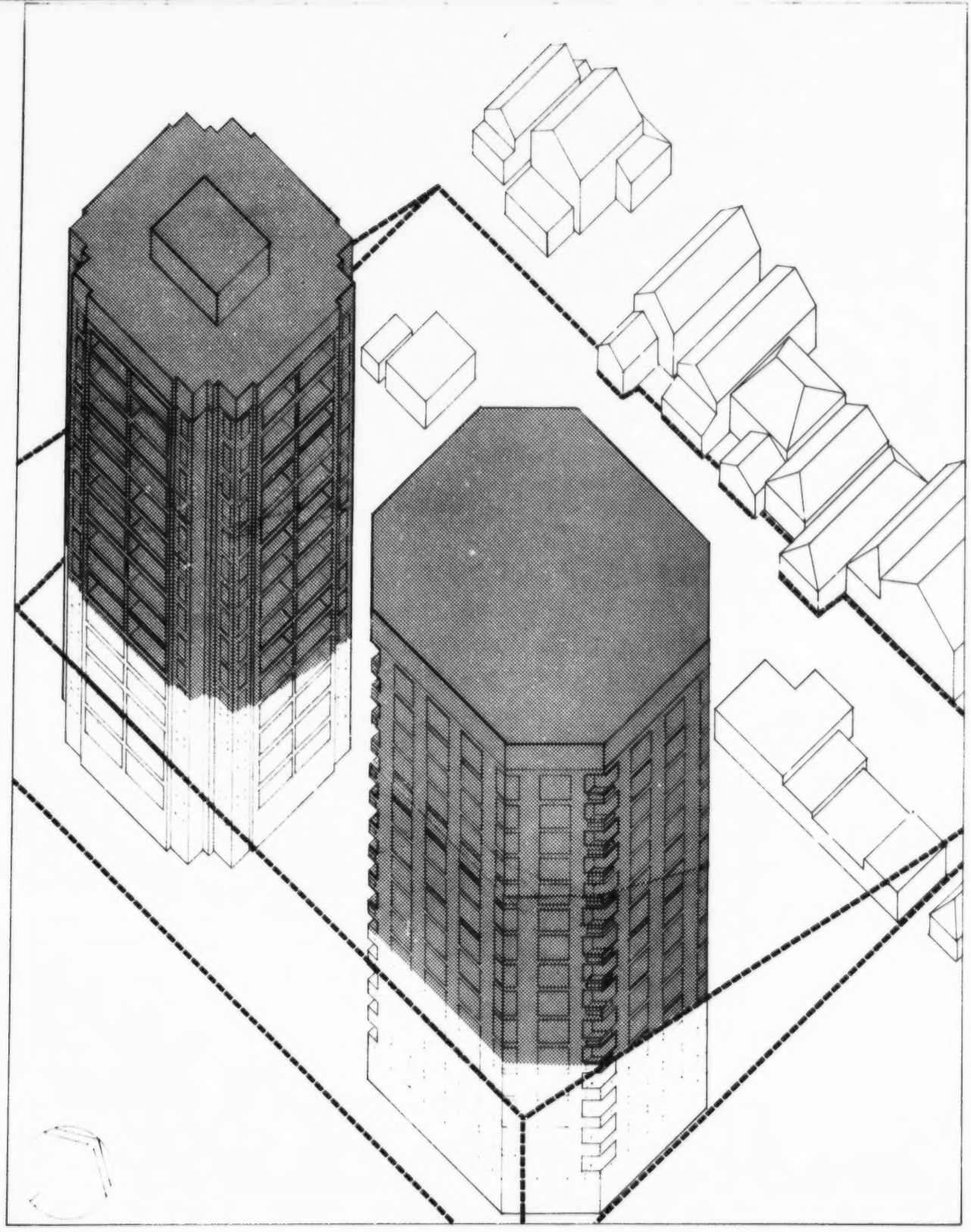


DIAGRAM 15
SOLAR ENVELOPE - HIGH DENSITY

NOV. / JAN. 21
9 a.m. & 3 p.m.

0 5 10 15 25
metres



SOLAR ENVELOPES- SOUTH WALL PROTECTION OF EXISTING LOW DENSITY

NOV. / JAN. 21
9 a.m. & 3 p.m.

DIAGRAM 16

0 5 10 15 25 metres

3. Existing Development Case Study: Shadow Diagrams

To date solar access zoning has been applied primarily in new residential development where streets, lots and buildings can be deliberately oriented to make the most effective possible use of solar energy. However, the effects of solar zoning for new residential development are necessarily confined to a very small proportion of all housing. The vast majority of the housing stock in Ontario is in existence now, and has been sited and constructed without regard to potential solar gain. Advances in passive and active solar technology are demonstrating that older housing can be adapted to take advantage of solar gain,* with the addition of greenhouses, additional south-facing glazed areas, upgraded insulation, roof mounted solar collection devices, etc. In areas of single family housing where the orthogonal grid street network is oriented closely to the east west axis** there is a possibility of adding effective solar systems to significant amounts of existing residential development. Provided that the south wall of a building, or the solar collector, is generally oriented to the south, it can provide effective annual solar gain. Research conducted at Colorado State University shows that the collector can be oriented as much as 35^{o} from due south and still be 90 percent efficient.***

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* Reif, David K., Solar Retrofit, Adding Solar to your Home, Brick House Publishing Co., Massachusetts, 1981

** Note: For example, most of the south section of the City of Toronto (south of St. Clair Avenue) has a grid street system which is oriented with 26^{o} of due south (east west streets)

*** Protecting Solar Access: A Guidebook for California Communities, American Planning Association, March, 1980, p.96

The following series of shadow diagrams (Diagram 17) takes an existing six block area in Metropolitan Toronto as a case study for the development of solar zoning in a built community. The area in question represents one of the most difficult cases faced by a municipal planner. It was originally made up of single family housing, constructed in the 1920's and 1930's. The street pattern is a traditional grid with major streets having an east-west orientation. The area, close to the city core, is now in the last stages of a period of transition which began with the replacement of sections of single family housing by low rise apartments, and is now experiencing the development of high rise apartments.

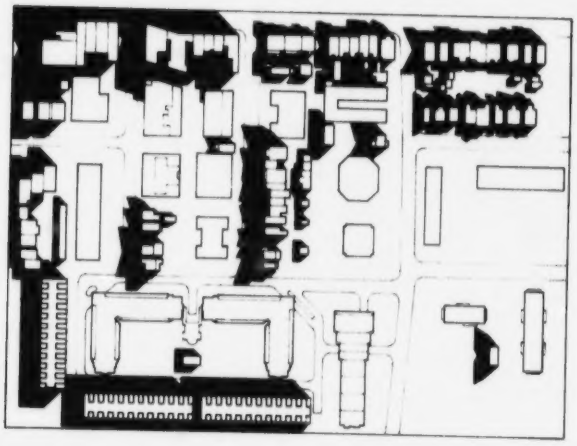
Shadow diagrams based on shadow patterns cast between 9:00 am and 3:00 pm on January 21st have been developed in stages, showing the shading impact of each successive intensification of density and height. It is important to note that these shadows are for a full day. At any one period the extent of shading would be much less than is shown.

Diagram 17a illustrates the shadows cast by the single family housing, most of which has a height of roughly 28 feet (9 metres).

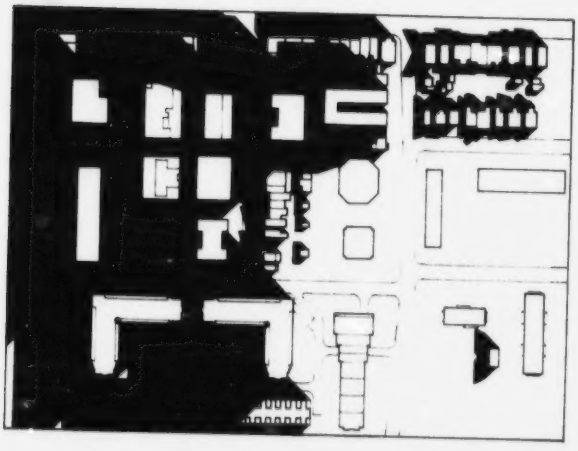
It is evident from the shadow patterns that the original fabric of single family housing, if undisturbed, could make use of solar gain with both south wall and roof top access, particularly for those houses situated on east-west streets. This diagram demonstrates that in areas where the consistency of scale of single family housing has been maintained, zoning to protect existing levels of solar access could be instituted.

Diagram 17b adds the shadow patterns cast by the medium rise multiple housing. The new medium rise apartment buildings (mainly built in the 1950's) are five to seven storeys in height (15-21

A



B



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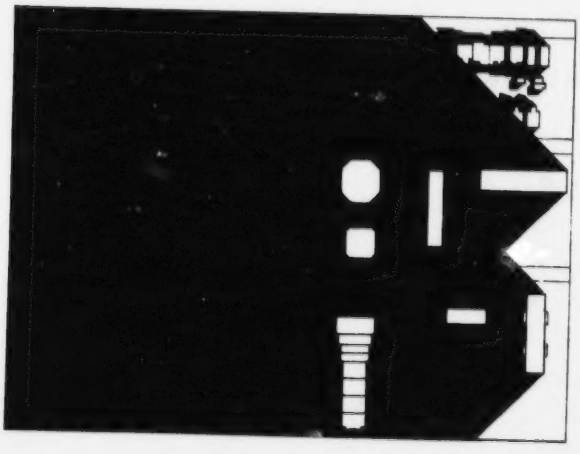

DIAGRAM 17
SHADOW DIAGRAMS - JAN 21, 9:00 a.m. TO 3:00 p.m.

metres). It is evident from the shadow diagrams that in the context of the existing block and street widths, these buildings effectively remove all potential solar access from the surrounding single family housing. However, they do permit roof top solar access for adjacent medium density buildings of similar scale.

Diagram 17c adds the shadowing effect of the recently built 17-20 storey high rise apartment towers. Because these buildings are clustered to the south of the existing development, their shadowing effect is predictably very severe. All solar access within roughly a two block northerly radius of these towers is removed from the lower housing, both low and medium density.

The study of this built area of the city tends to confirm conclusions arising from the study of alternative forms and densities of new housing.

- Passive solar access (south wall exposure) cannot readily be achieved for all houses in most urban areas, even in new subdivisions. Only those units which have a full south orientation (primarily those on east-west streets) will be able to take full advantage of solar gain during the effective heating period. However, this condition already exists for a fairly large percentage of houses even in older built areas and particularly where a grid system has been used.

- Areas of existing single family housing which have retained a consistency of height and setback provide the best opportunity to introduce solar access protection. It must be recognized that the introduction of solar access zoning in such areas would largely prevent their redevelopment at higher densities.

- Passive solar access which requires south wall exposure is achievable only in areas of single family housing, or in multiple housing up to a maximum of 25 - 30 units per acre (depending on typical lot sizes and topography) in Ontario latitudes.

- Height limits which impose a relatively uniform height on higher density areas are most effective in protecting roof top solar access for the present or future use of active solar systems.

III Zoning for Solar Access - Implementation

It is generally agreed that municipalities in Ontario have the authority under the Planning Act to pass by-laws which protect solar access. Solar zoning by-laws which use height and setback regulations to create a solar envelope are thus practical and enforceable in Ontario.

With an understanding of the basic concepts of solar access, and the effects of applying these concepts to both new and existing development, the planner can consider alternative ways of implementing solar zoning legislation. The steps required for implementation of solar zoning are:

1) Amendment of the Official Plan to include policies which support the use of solar energy as part of an overall municipal energy policy.

2) Review of existing zoning by-laws to remove barriers to the use of passive or active solar systems. (eg. inclusion of solar equipment as a permitted use, review of height limits).

3) Consideration of policy conflicts between solar access protection and other municipal objectives.

4) Decision about appropriate methods and levels of solar access protection in the zoning by-law.

1. Official Plan Policies

Where a municipality has decided that it wishes to enact zoning by-laws to protect solar access, policy statements which support the encouragement of solar energy use should be included as an amendment to the Official Plan.

The legitimacy of solar access zoning by-laws is considerably strengthened when they are made within the framework of a clear set of Official Plan policies. The City of Brampton, whose use of solar zoning in new subdivisions has been challenged and upheld at the Ontario Municipal Board, has included the following statements regarding Solar Energy in its Official Plan:

1.4 ENERGY CONSERVATION

1.4.1.5 Council shall encourage and support the practical application of innovative ideas relating to energy conservation through site planning, building design, renewable energy, alternate energy and efficient equipment.

1.4.1.6 Council shall require the design of residential, commercial and industrial subdivisions and siting of buildings for proper sun and wind orientation to the extent practicable.

1.4.1.7 Council shall encourage use of appropriately selected and located vegetation that will reduce the energy consumption of buildings.

1.4.1.8 Council shall ensure, where practicable, access to direct sunlight during winter daylight hours for all potential solar collector panel locations and solar oriented glass on all existing and future buildings in Brampton.

2. Barriers to Solar Access in Existing Zoning

It is essential to review existing local by-laws to ensure that they do not prevent the use of solar collectors. The following is

a check list of sections of the zoning by-law which may require modification in order to make solar access possible:

Definitions:	Additions to the definitions section to include the wording necessary to describe solar collectors and building envelopes.
Permitted Uses:	Ensuring that solar collection devices are a permitted use in all areas (particularly in residential areas)
Height and Setback Regulations:	Ensuring that height and setback regulations do not preclude the use of solar collection devices.
Maximum Coverage:	Ensuring that maximum lot coverage regulations and regulations covering accessory structures do not constrain the ability to add solar collection devices to an existing building or property.
Heritage Easement Agreements and Architectural Controls:	Examining the provisions of heritage building designations and easements, and heritage district designations to assess their potential for prohibiting or constraining the use of solar collection devices.

Definitions

It is essential that the terms required to describe solar technology and solar envelopes be defined in the introductory definitions section of the by-law. Terms such as "solar energy", "active and passive solar energy systems", "altitude", "azimuth",

"solar collector", must be defined in order to allow effective by-law definition. Further it is important to clarify where heights are measured from, especially on sloping sites or sites with irregular grade levels.

Permitted Uses

Solar collection devices, particularly if they are built as a separate structure, may not be considered a permitted use in residential zones. It may be necessary to include in the zoning by-law a statement specifically making solar collection devices a permitted use with consideration of the extent to which they should conform to height, setback or total allowable coverage regulations. Roof mounted solar collectors may be prevented by existing height regulations, and should be considered for exemption, provided they do not cause shading of other collectors.

Architectural Control

In Ontario, buildings and districts which are designated under the Ontario Heritage Act are subject to architectural controls. Some planned residential subdivisions are also regulated in terms of additions to buildings, colours and materials. The effect of these regulations on the ability of the individual owner to add solar collecting devices to his house must be considered by the local planner.

3. Conflicting Policies

The issue of potential conflict between solar energy use and aesthetics or heritage preservation areas is an area which must be carefully considered by the municipal planning agency. There are several possible points of conflict between policies which

encourage solar energy use, and other important local policies and objectives. For example, heritage district preservation policies often include architectural provisions for façades which would not allow solar collection devices, greenhouses reflectors, etc. Local policies which encourage higher density forms of housing can conflict with objectives for solar energy use, which requires low building forms and relatively wide spacing. Yet both medium and high densities and solar energy contribute in differing ways to community wide energy savings.

The planting of street trees and trees on private lots is another example of a policy which is strongly encouraged, indeed required by many municipalities, but which can cause serious problems for access to solar radiation. Depending on the species, deciduous trees, even when they have shed their leaves, can obstruct anywhere from 20% - 80% of available solar energy. Street trees bring a highly desirable level of amenity to a residential neighbourhood, one which few municipalities would be willing to forego. In Ontario latitudes, it is almost impossible to plant street trees in such a way that they do not cast shadows on the south facing walls of adjacent housing. Thus it may be necessary in new subdivision plans to specify species of trees which have a light branching pattern, and cast the slightest possible shade, and to regulate the spacing of street trees in such a way that they create the minimum possible winter shading.

4. Inclusion of Solar Access Protection in the Zoning By-law

Solar zoning can be applied to a new residential development with little controversy or difficulty. Where there is the flexibility to orient streets and lots with minimum constraint, it is a relatively simple exercise to ensure that a large percentage of lots have a southern exposure, and that houses are sited in such a

way that they do not shade each other. The builder can use solar systems in the housing or not, as he sees fit, but in the long term, the potential to add solar technology in the future is protected.

The majority of Ontario's housing is in existing built areas, where considerations of solar access were not part of the original site planning. However, if solar gain is to have a real impact on Ontario's long term energy usage, it will be essential to apply solar zoning to these built areas. For the local planner who wishes to consider such a course of action, the following is a suggested approach:

i) Determine public awareness of the need for energy conservation and of the potential individual benefits in annual heating costs to be gained from the use of solar technology in an existing house.

ii) Determine the degree of solar access existing in the area under study.

iii) Based on the results of ii), decide on levels of solar access protection appropriate in the study area.

iv) Consider areas of possible conflict between solar access and other community objectives.

v) Begin the process of drafting Official Plan and zoning by-law policies, public review, etc.

Public Awareness

In spite of the growing recognition of the importance of solar gain in reducing individual consumption of fossil fuels for home

space heating, public awareness of solar technology is still very low. Where solar zoning is to be added to the existing zoning for a built residential area, additional building restrictions will be imposed on the property owner. It will be important in these areas to initiate a program of public information and discussion in order to broaden the general awareness of solar systems and the need to protect the potential for their use by present and future owners. Without public understanding and support, solar access protection policies may face strong opposition from individual property owners who recognize only that their development rights are being restricted.

Methodology for Determining Existing Solar Access

As discussed in the earlier chapters, latitude, climate and topography are all important elements in determining local solar gain potential. In an existing built area, however, the orientation of streets, patterns of built form, existing vegetation and slope are all critical determinants. In order to zone for solar access, the planner must first conduct basic data gathering to learn the levels of existing solar access. In other words the amount of shading occuring in the study area must be catalogued. There are several alternative means of accomplishing this:

- Aerial photography of the community at three periods during the day (9:00 am, 12:00 noon, 3:00 pm) on a sunny day as close as possible to November 21 and/or January 21.

- The calculation of shadow patterns for each building in a community between the hours of 9:00 am and 3:00 pm on January 21/November 21.

- A field survey of a representative sample of house and lot conditions at three periods during the day (9:00 am, noon, 3:00 pm) of the patterns of shading in a selection of areas which represent typical local conditions of building type, density, street width and orientation, slope and maturity and placement of vegetation. While less accurate than the two preceding methods, this may be a more practical approach, particularly in a large community in which there are discrete areas which are relatively homogenous.

The first of these methods, aerial photography, is perhaps the simplest method of determining the existing situation. However, it is expensive and is dependent on sunny weather on a date on or very close to January 21/November 21. A combination of the second and third methods is an alternative method, requiring that the planner conduct and map the necessary shadow diagrams.

Determine Appropriate Solar Access Protection

Depending on the results of the analysis of existing shading, the planner must decide on appropriate levels of protection. Generally the maximum possible level of protection should be assured, without creating large areas of buildings which become non-conforming uses. Thus in a stable low density neighbourhood where buildings are low and widely spaced, south garden access may be protected. In denser areas of single family housing south wall access, or access to upper portions of the south wall may be protected. The most limited useful form of solar access is south roof, which provides only the potential for future roof-mounted active solar systems. Since these roof-mounted systems are technically more limited in their application to existing standard

housing than passive systems, every effort should be made to secure some level of south wall access. It should be kept in mind that in most areas of Ontario the heating season begins in October and continues until May. Consequently even where solar access is limited in winter months, effective solar heating may be used in the "shoulder" seasons of fall and spring, when shadows are shorter.

Areas of Potential Policy Conflict

As discussed in the earlier chapter, there may be policies of tree planting, heritage conservation, architectural control or increased density which conflict with solar access protection policies. As part of the public review process, the planner must identify these conflicts and attempt to find acceptable means of accommodation or resolution. The successful resolution of these conflicting objectives will contribute significantly to widespread public acceptance of solar zoning policies.

Draft Official Plan and Zoning By-Law

It is important to include specific policies in the Official Plan which set the framework for energy conservation and the protection of solar access as a community wide objective. The zoning by-law may then be drafted to implement these policies. The following section discusses the alternative approaches to a solar access zoning by-law.

5. Prescriptive Zoning versus Performance Standard Zoning

There are essentially two approaches that can be taken in formulating a zoning by-law to protect solar access. The first approach is traditional prescriptive zoning in which specific uses

are permitted in each zoning district. The physical form and siting of buildings which fall within the permitted use categories are regulated by setback requirements, height regulations and controls such as requirements for access, parking, loading and landscaped open space. Both the planner and developer know precisely what the rules are and it is relatively simple to judge whether a development is in compliance with the zoning by-law. Minor variations to deal with special site conditions are dealt with through the Committee of Adjustment.

Performance Standard zoning can also be used to control solar access. Performance Standards differ from Prescriptive zoning in that they specify minimum or maximum levels of performance, rather than defining exactly what can or cannot be done. For example, the City of New York uses Performance Standards to award "points" to the developer of a property for levels of amenity, achieved by a development, such as the amount of daylight penetrating to the street level. Prescriptive zoning would in this instance define precisely the setbacks and angular planes required to achieve daylight on the street.

Performance Standard zoning has the advantage of allowing the developer the flexibility to design his building in any way which meets the performance standard. However, it places considerably more onus on the planner who must evaluate the design to ensure that it complies with the standards.

Prescriptive Zoning For Solar Access

There are four potential ways of using prescriptive zoning regulations to protect solar access. These are:

1. Changing maximum building heights.
2. Reducing the requirement for minimum lot frontages on east-west streets while maintaining minimum lot sizes. The result is deeper north-south lots and improved solar access.
3. Increasing front and rear yard requirements while decreasing side yard requirements on east-west streets to produce a wider, shallower house with increased south wall exposure.
4. Developing a solar building envelope with the height limit defined as an angular plane, in place of a standard height limit.

Reduced Height Limits

A simple reduction in height limits can in some areas be an effective means of protecting solar access. In many existing residential areas where houses are one and two storeys in height, virtually all buildings are under 9 metres (30 feet) in height. Thus a 9 metre height limit would not be onerous, and would provide considerable south wall solar access in normal single family lot configurations. But many of these areas have a permitted height of 11 metres (35 feet), a height which would block south wall solar access for at least part of the day. Reducing height limits to the scale of building which prevails in a residential area is neither complex nor unduly restrictive and in many existing areas of single family housing such a height reduction could substantially improve levels of solar access protection.

Reduced Minimum Frontage Requirements

Frequently zoning by-laws for residential development specify a minimum width for the frontage of a lot onto a street. A common minimum single family lot frontage in zoning by-laws

of the past was 60 feet (18 metres). More common recently are smaller frontage of 50 - 30 feet (15 - 9 metres). Assuming that the lot size remains constant, there are advantages for solar access in reducing lot frontage requirements on east-west streets. Narrower, deeper lots produce wider spacing between units in a north-south dimension, and thus give greater solar access to south gardens and walls within the same overall density.

Modified Setback Requirements

Front yard setback requirements which require that houses be set back from the street can, on east-west streets, result in excessive shading on south facing walls and gardens. Front yard setback requirements can be reduced to create greater spacing between north-south building, or alternatively the zoning by-law can require that houses be built at or close to the north lot line where this lot line fronts on a street.

Solar Building Envelopes

The solar envelope has been described in some detail in the previous chapter. Amending the zoning by-law to create solar building envelopes requires that height and setback regulations be changed to coincide with the sun angles needed to protect solar access to surrounding properties.

The first requirement is to set the horizontal plane from which all heights will be taken. This should be the average grade level across the lot or the average grade level along the lot line which separates properties. The height of the building must then be defined as the highest point of the building, rather than as a mean point between the peak and

the eaves (a normal definition of height for pitched roof buildings).

It is essential that the appropriate level of solar access be decided for each zone. For example, in single family residential areas the optimum protection is for solar access to the full south garden. The minimum requirement to protect future passive solar use is protection of the south wall. In higher density residential zones south wall access is ideal, but roof top solar access may be realistically the only level of protection which can be achieved.

Once the required level of solar access protection is determined, the building envelope can be developed. This is essentially a variant on traditional height and setback regulations, which applies a bulk plane instead of a uniform height limit. The bulk plane provides that as the setback increases, the height can increase. It will always be highest at the south end of the lot, and its angle will ideally be set by the angle of altitude of the sun on January 21 and November 21, for the latitude of the community in question. This information can be obtained from the Sun Shadow Guide, Ministry of Energy or from the ASHRAE Handbook of Fundamentals, published by the American Society of Heating Refrigeration and Air Conditioning Engineers. The point of origin of the angle is:

- The rear lot line if the south garden is to be protected
- A point at the base of the south wall above which windows might be placed (approximately 0.6 metres above grade) if the south wall is to be protected. Where no building exists on the lot the point of origin of the angle would be the rear yard set back line.
- The south boundary of the roof line if the roof is to be protected.

Where lots are ideally oriented on a direct north-south axis, and the community is flat, the calculation and application of these building envelopes is relatively simple. Even where the orientation of the buildings is not due north-south, the building envelope can be calculated and regulated without undue difficulty. Where the community has a significant rise and fall in the land, however, the calculation of the envelope must take into account the degree of the slope. Formulae to make this calculation, and shadow length multipliers for a series of conditions of latitude and slope are given in tables published in the Sun Shadow Guide, Ontario Ministry of Energy.

Performance Standard Zoning

As an alternative to prescribing the exact setbacks and angle of the bulk plan for each lot, which requires that a fairly complex set of calculations be made, the municipal planner may choose to use performance standard zoning.

In essence, the performance standard zoning for solar access permits buildings and vegetation on a lot provided they do not cast shade on a prescribed area of an adjoining lot. The developer has the freedom to meet this requirement in any way he can devise. A performance standard mechanism which has been used in California is a hypothetical wall placed on the boundary line between two lots. The area of the lot on which the hypothetical wall would cast shade is the only area of the lot which an adjacent building may shade. The height of this hypothetical wall is calculated to ensure south wall solar access. The result is an effective building envelope which starts at the top of the wall and rises on the angle of the sun's altitude on January 21. Diagram 18 illustrates this concept. The hypothetical wall at the rear property line of lot A prescribes the only portion of lot B which may be shaded by a building on lot A. The performance standard

by-law simply sets the height of the wall and requires that the building on lot A, the lot to the south may cast shadow only in the area which would be shaded by the wall on January 21 and November 21 between 9:00 am and 3:00 pm.

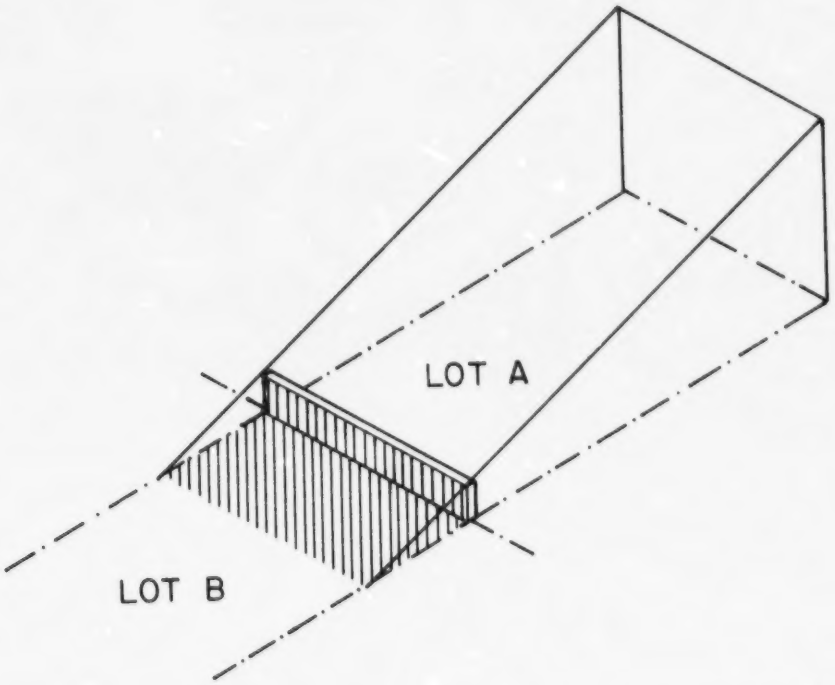

DIAGRAM 18- PERFORMANCE STANDARD ZONING- HYPOTHETICAL WALL AND RESULTANT SOLAR ENVELOPE (LOT A)

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